MAHARANA MEWAR PUBLIC SCHOOL

Session: 2025-2026

Pumping Heat like Water

Class:- XII - D

Subject:- Physics (042)

Board Roll No. :-

Submitted By:- Taha Husain

Submitted to:- Dr. Rakhee Trivedi (PGT - Phy)

Certificate

This is to certify that **Taha Husain** of **Class XII-D** of **Maharana Mewar Public School** has completed his project **(Pumping Heat like Water)** under my supervision. I certify that this project is up to my expectations and as per the guidelines issued by the **Central Board of Secondary Education**.

Signature
Examiner

Signature
Dr. Rakhee Trivedi (PGT - Phy)

Acknowledgement

I take this opportunity to express my profound gratitude and deep regard for my guide Dr. Rakhee Trivedi's encouragement throughout the course of this project, for her amazing guidance, and wisdom.

I also want to thank my peers who helped in developing the project, and people who have willingly helped me out with their respective abilities.

Introduction

So, On one fine day in our Summer Break, I was wasting my time watching YouTube, And I stumbled upon a video from a channel called ‘ElectroBOOM’ about Cloud Chambers.
In the video, The host was making a Cloud Chamber using a device called a ‘Peltier Module’, and just like that i was invested.
The very next day, I went out into the market, Blew off ₹500 and got myself a 4 cm * 4 cm Square called a Peltier Module.

I started experimenting with the Module and was amazed how i just gave it power and part of it cooled down, So I dug into some of it’s inner workings on the Internet and decided to make my Physics Project Report on it.

Oh and, There is another thingy I decided to make with the Peltier Module, which led me to Mumbai!

But, Without Further ado,
Welcome to re-Discovering the Heat Pump!

Aim

The Aim of this project is to explore the concept of ThermoElectric Cooling, along with documenting and explaining all that I read and understood about the Peltier Effect and how it leads upto Heat Pumps.

How do you “pump” Heat like it’s Water?

Well, Pumping Heat is a pretty simple concept, honestly.
Naturally, In 2 Objects (A & B), Heat flows from Higher → Lower, Basically Heat flows from a Higher Temperature to a Lower Temperature if they are connected by a Thermal Conductor (Just like Water flows from High Pressure → Lower Pressure) (By Temperature here, I mean the degree or intensity of Heat present in an object (Here i am using °C)).
This heat transer keeps happening until both the Objects are in Thermal Equilibrium (Fancy word which means having the same temperature).
But now, If we introduce a “Heat Pump”, We resist this natural Flow and move heat from say A → B even when B has Higher Temperature than A.
We can achieve this by just absorbing Heat from A and continously depositing it in B.
But to resist this Natural flow, We need to provide energy to the Pump.

And this is where some amazing people like Sir Thomas Johann Seebeck & Sir Jean Charles Athanase Peltier!

The Discovery that led to the Heat Pump (No, I didn’t invent them :/)

So, It was a fine day in 1821, Sir Thomas Johann Seebeck was sitting in his Workshop tinkering away with his stuff. When he noticed something strange...
When he joined two different metals and heated one of them using a Bunsen Burner. A nearby Compass Needle twitched slightly, This could only mean 1 thing! Electric Current!!

As expected, He was immediately interested in it. He did some further experiments and noted down these results. He invented a new quantity named the 'Seebeck Coefficient' and moved on to other experiments (Yeah, Inventing stuff back in the day was just another Tuesday for scientists).

But approximately 13 years later, Sir Thomas Johann Seebeck happened to stumble upon these Notes about a mysterious phenomenon where Electricity was being produced by a Temperature Gradient between 2 Metals.

So he Himself started tinkering with this concept and found out the same thing. But this time, He thought what would happen if he flipped this concept 180°.

He thought about what would happen if he instead passed an Electric Current between these connected Metal Plates instead.

And so he did, And he found out that when some Electric Current was passed through them, One of the Metals cooled down and the other one heated up!!

And thus, The Heat Pump was invented!

A way to tranfer Heat against it's natural flow!!

Sir Thomas Johann Seebeck

(Source - Wikipedia)

Sir Jean Charles Athanase Peltier

(Source - Wikipedia)

Alright, But how do these Heat "Pumps" work?

I am glad you asked!

Alright, So now imagine a metal conductor closely. There are electrons in the Metal. Now, if you connect the original Metal with another different Metal (Different element, Not just different dimensions) (And by connect I mean basically just putting 2 things together so they are in contact with each other).... Well Nothing happens, They are just 2 Metals in contact with each other

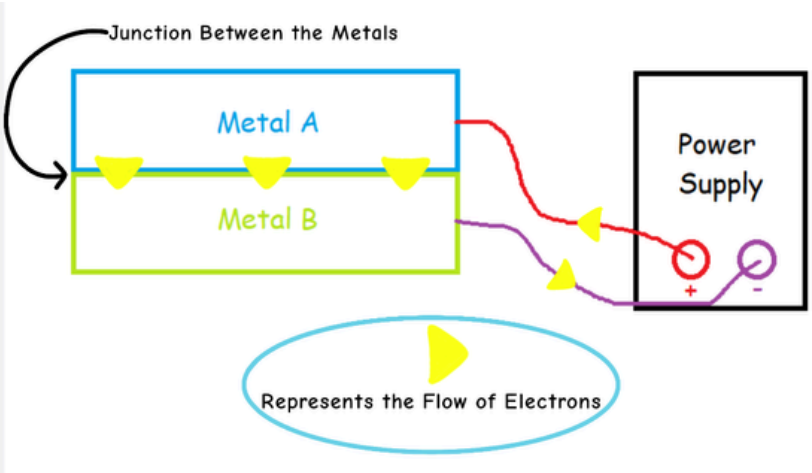
The Real magic starts occurring when there is a net flow of electrons from one of the Metals to another.

This can occur if we connect the Anode (+) of an Electric Current Supply to one of the Metals, Say Metal A

And the Cathode (-) of the Current Supply to the Metal B.

Considering Metal A & B are Connected together, This should essentially complete the circuit and let the current flow.

Here's a Diagram showcasing the Arrangement (Source - Drawn by Me :D):



Now, When the electrons try to flow through the junction of the 2 Metals, They will require extra energy to do so (cross the junction) because of the properties which originates from the differences in the Metal's Electronic Band Structures and the different ways in which Electrons transport energy in different elements. These properties give the Metals their own unique 'Seebeck Coefficient' (As described previously). The higher the difference between the Seebeck Coefficients of 2 metals, The Higher the magnitude of the Seebeck/Peltier Effect between them.

So, The Electrons will require extra energy to balance the "energy mismatch" to "bridge" the junction.

But, Where do electrons get this extra Energy?

They Can't take it from the Power Supply, as that is only giving out a constant Voltage/Energy.

Now, With no other Input of Energy, Electrons take this Extra Energy from Metal A (In the form of Heat)! (Yeah i know, They are basically thieves at this point). After this extra Energy input, Electrons are able to “Jump” the junction and arrive in Metal B.

The electrons now arrive in Metal B with extra energy (Energy which was required to pass through the Junction). But don’t worry, Electrons are not Criminals. They give back this Extra Energy that they “Stole” from Metal A (The Scientific reason is that Electrons cannot enter the Power Supply with more energy than what they started with, as this would “destabilise” the circuit). So, The Electrons deposit this Extra Energy into Metal B, and now you should be able to guess what this extra energy does to Metal B!

That’s Right! This Extra Energy essentially Heats up Metal B!

And then the electrons complete their short journey and re-enter the Power Supply.

All of these concepts come together to make a Functioning Heat Pump! Also known as a Peltier Device in honour of the discovery by Sir Jean Charles Athanase Peltier.

Peltier Modules in Real Life (The Interesting Bit!)

Now, I know how amazingly fascinating this concept of a Heat Pump is!

But the first working device made by Sir Peltier wasn’t really efficient and barely usable in real-life scenarios.

But worry not! We can increase the Efficiency of these Peltier devices by using Semiconductors in them instead of any normal Metal (Because we can fine-tune and adjust the Energy Band Structures of Semiconductors according to our needs).

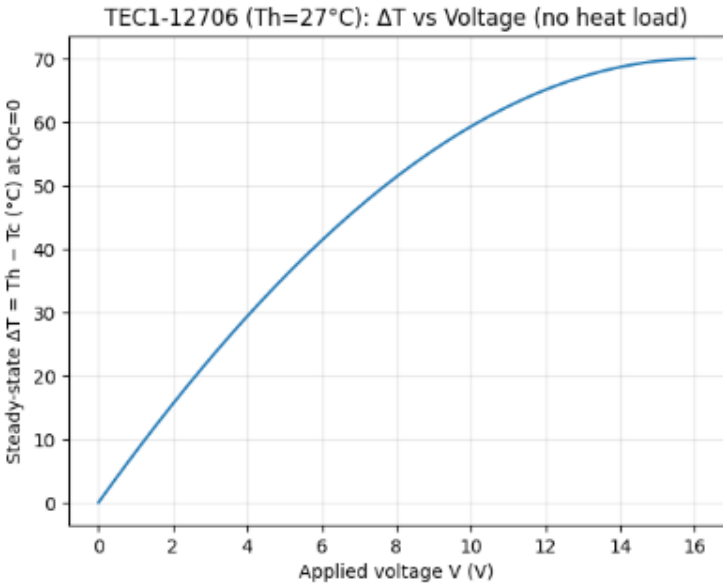
In today’s time, Efficient Peltier Modules are available in the market cheaply for Hobbyist and Industrial Usage.

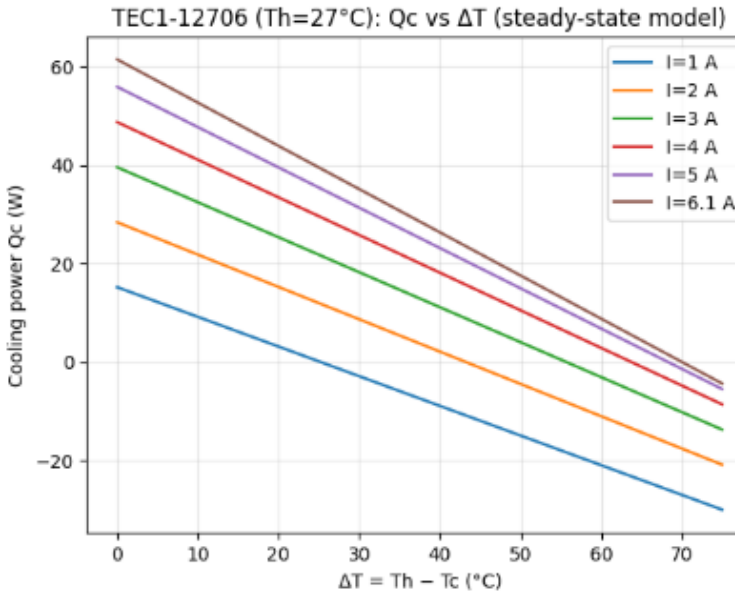
For example, the Peltier Module named ‘TEC1-12706’ (I know very uninteresting name) uses an array of Bismuth Telluride semiconductor pellets (Now That’s a cool name!).

Image of a TEC1-12706 Peltier Module (Source - Google)

And this is the one I bought from the market for tinkering. It costed me ₹500 when i bought it, but now i believe that it is available for ₹250 only.

And these 4*4 cm square thingys are extremely efficient! Here are some graphs conveying the same thing:





- The Graph on the left shows the Increasing temperature difference (in °C) between the Hot and Cold sides of the Module with increasing Voltage (in V) supplied to it (With no Heat Load and Ideal Conditions). The Trend indicates that after a certain Voltage, The Cooling Power gained is negligible. That means Peltier Modules are made to operate on certain voltages only.
- The Graph on the Right shows the Amount of Cooling (in W) the module can provide for a given Temperature difference (in °C) between the 2 sides for different fixed values of input Current (in A). The trend shows us that the Cooling power decreases as the Temperature difference between the two sides increases, and that Higher Current values directly dictates to higher cooling power.

Heat Pumps Beyond just the Concept - ThermaVault

So, After all of this Research about the Peltier Module was done, and I had tinkered enough with the module (I actually broke the 1st module I had as I input too much Voltage into it 😅, So i Had to buy another).

I decided to use some of my Arduino and Heat Pump Knowledge to make a Sustainable Solar-Powered Cooling Box, specifically used as Cold Storage for Medicines and Vaccines.

I named it 'ThermaVault' and participated in the Western India Science Fair 2025.

Now, I did not expect to go anywhere with this project. But guess Fate had different plans for me!

I secured 1st Position in District (Udaipur), 4th Position in States (Rajasthan) and was able to represent my state in the Nationals of WISF 2025 in Nehru Science Center, Mumbai!

So, I guess a little curiosity and research does go a very long way!! :D

ThermaVault on Display in Nehru Science Center, Mumbai for WISF-2025

For anyone interested, Further information about ThermaVault is available on my GitHub Repository: https://github.com/AstroSparrow/ThermaVault

Bibliography & Credits

Information Sourced From: Wikipedia (The Wikimedia Foundation), YouTube (Special Shoutout to ElectroBOOM!), Reddit, The Internet Archive, ScienceDirect.com, Google (And Articles sourced from Google)

Software Used: Microsoft Paint, FlipaClip, Python 3.14.0 (Matplotlib & Numpy), Canva

Information Compiled By: Your's Truly, Taha Husain! :D

The Conclusion (At Last!)

I had a lot of fun researching about the inner workings of these fantastical devices, and I had even more fun making this project to try and explain all that I had learnt about them!

And turning this research into a Physical project and being able to represent it at Nationals was just another level of excitement!
I am truly blessed to have such amazing parents, peers, teachers and resources that allow me to do all of these crazy shenanigans!

The concept of a ThermoElectric Cooler/Heatpump also proves to me how many such amazing discoveries still exist beyond the horizon, Waiting patiently for a curious soul to wander on by and find them.
I am so excited by the prospect of research in Physics, and I plan to make this my life-long passion and goal!
This reminds me of a quote from Sir Stephen William Hawking:
"Always try to look upto the Stars and not down at your Feet. There is still plenty more out there to find out"

So, For now, I'll let the concept of Heat Pumps be my latest "Re-Discovery", until I inevitably move onto some other even more fascinating concept in the future!

Lastly, I would like to thank the reader for making it this far and not being bored by all of my nonsense, excited rambling in this entire report. I hope that you learnt something new about out marvelous cosmos through this Project!
ThankYou So much for your patience

This is Taha, Signing Off! :3